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Research Article

Evaluation of the Application Effect of Contrast-Enhanced Ultrasound Image Technology Based on Three-Dimensional Image Fusion Algorithm in the Diagnosis of Adenomyosis

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In this paper, the effect of ultrasound images based on a 3-dimensional image fusion algorithm in the diagnosis of adenomyosis was evaluated. 88 patients with adenomyosis who were treated in the hospital from February 2019 to May 2020 were selected as the research subjects. They were rolled into localized type (Group A), with 40 cases, and diffuse type (Group B), with 48 cases. At the same time, 45 women of normal childbearing age who underwent physical examination in the outpatient clinic were rolled into the control group (Group C). Three-dimensional ultrasound scans of the uterus were performed on all patients, to observe the enhancement methods and characteristics. Then, the image characteristics of adenomyosis were studied through the time-intensity curve (TIC). Arise time ATs of three groups of patients were not different greatly ($P > 0.05$). It was found that the enhancement method, enhancement uniformity, and enhancement level of ultrasound scan in Groups A and B were significantly different from Group C ($P < 0.05$). In contrast with Group C, the rise time (RT) of the ultrasound scan of the two groups was less, the time-to-peak (TTP) was faster, and the image maximum (IMAX) was higher ($P < 0.05$). What is more, contrast-enhanced ultrasonic (CEUS) detection in patients with adenomyosis showed centrality and nonuniform high enhancement. Besides, less RT, faster TTP, and higher IMAX than the normal population can be the key evidence for the clinical diagnosis of adenomyosis. In conclusion, according to the blood supply characteristics of adenomyosis and other gynecological diseases, the enhancement method and enhancement time of ultrasound images are significantly different. TIC can reflect the hemodynamic difference between the lesion and the normal ones. Therefore, the CEUS based on the three-dimensional image fusion algorithm can be applied to the image diagnosis of adenomyosis.

1. Introduction

Adenomyosis is a common estrogen-dependent disease. The cause of the disease is the invasion of the uterine muscle wall by the endometrium. The main pathological features are dysmenorrhea, increased menstrual flow, and anemia [1], along with endometriosis, uterine fibroids, and other problems [2]. Clinically, adenomyosis can be classified into the diffuse type and localized type according to the location and range of the ectopic endometrium invading the uterine muscle wall [3]. A common treatment for adenomyosis is hysterectomy, in which the wall of the uterus opens and the muscles of the uterus thicken and harden significantly. Besides, there is no obvious and regular myoma-like vortex structure on the pathological section [4], and only thick muscle fiber bands and microcapsules can be seen in the muscular wall. A small number of endometrial muscle layers grow locally, forming nodules or masses, called adenomyomas. The difference between adenomyoma and fibroids is that adenomyoma does not have a surrounding envelope, nor does it have a boundary with the surrounding muscle layer. Therefore, it is difficult to separate from the muscle layer. Microscopic examination of the muscle layer shows endometrial glands and stroma [5–7].

Pathological diagnosis is the gold standard for the diagnosis of adenomyosis. However, in clinical applications, most doctors and patients believe that imaging examination is a commonly used and effective method. In addition, commonly used measures include transvaginal ultrasound and transabdominal ultrasound, MRI, CT, and CEUS [8]. In CEUS, the contrast medium is injected into the blood vessel through the vein, and the perfusion of the contrast medium in the muscle layer and various tissues is observed. In the angiographic examination of adenomyosis lesions, the enhancement methods include synchronous enhancement, uneven enhancement, and centripetal filling [9–11]. The boundary of the lesion in conventional ultrasound examination is often not clear enough, while CEUS can clearly show the extent of adenomyosis lesion. Three-dimensional ultrasound imaging technology can collect data on the target area in a short time and use multiple imaging modes for three-dimensional reconstruction according to different purposes [12]. Three-dimensional ultrasound imaging technology combines the advantages of CEUS and three-dimensional ultrasound imaging technology, which can obtain blood perfusion information of the target area from a three-dimensional perspective. Furthermore, the CEUS detection of adenomyosis through the three-dimensional image fusion algorithm can simplify the patient's diagnosis process, improve the detection efficiency, and bring convenience to both the doctor's diagnosis and the patient's medical treatment.

Image fusion technology is a novel multimode medical image development method. Specifically, images acquired by different medical imaging devices are processed to achieve pairing on spatial coordinates, and complementary information is obtained after image superposition [13]. The key point of image fusion is the precise alignment between the two images. To improve the success rate of alignment fusion, the following points should be noted. Images with small time difference are selected for fusion. The blood vessel area is mostly suitable for fusion. In addition, the patient should breathe smoothly during the alignment process. In summary, the effect of CEUS in the diagnosis of adenomyosis based on the three-dimensional image fusion algorithm was explored in the study. The main content includes the generation of three-dimensional ultrasound contrast, the detection results of three-dimensional ultrasound contrast, and the comparison of the parameter level of the TIC.

2. Materials and Methods

2.1. Research Subjects. A total of 88 patients with adenomyosis who were treated at our Hospital from February 2019 to May 2020 were selected as the research subjects. According to the clinical characteristics, they were rolled into localized type (Group A), with 40 cases, and diffuse type (Group B), with 48 patients. Inclusion criteria were as follows: patients with adenomyosis between the ages of 20 and 60, who signed the informed consent forms. Exclusion criteria were as follows: patients with contrast agent allergy; patients with a history of radiotherapy and chemotherapy; patients with a history of endometrial trauma operations; patients with severe cardiovascular and cerebrovascular diseases; and patients with severe mental illness. At the same time, 45 women of normal childbearing age who underwent physical examination in *X* hospital were rolled into the control group (Group C). The general data of all subjects were as follows: in Group A, the ages were between 28 and 50 years, with an average age of 37.2 ± 5.2 years, and the body mass index was $23.6 \pm 1.2\,kg/m^2$. For Group B, the ages of the patients were between 26 and 52 years, with an average age of 36.3 ± 5.8 years, and the body mass index was $22.6 \pm 1.1\,kg/m^2$. For Group C, the ages were between 26 and 50 years, with an average age of 35.8 ± 6.2 years, and the body mass index was $23.2 \pm 1.3\,kg/m^2$. There was no obvious difference in the age and body mass index between the three groups ($P > 0.05$). This study had got permission from the ethics committee of *X* Hospital.

2.2. Detection Methods. Philips iU22 was adopted, equipped with PercuNav 4.0 system, and the contrast agent was SonoVue (Bracco Suisse SA). For the C5-1 probe, the frequency of the transvaginal probe was 5.0–9.0 MHz, and the frequency of the transabdominal probe was 1.0–5.0 MHz.

The patient's bladder lithotomy position was examined. First, the patient's uterus, double appendages, and the entire pelvic region were observed. Then, two-dimensional ultrasound images of the patient's lesions were obtained. The location, size, boundary, shape, and internal echo were mainly observed. Then, the color Doppler blood flow imaging technique was adopted to detect the blood flow direction and distribution in and around the patient's uterine lesions, so as to clarify the sections that need to be observed during the CEUS. The detection method was determined according to the results of the two-dimensional ultrasound image. The probe was placed at the best detection surface, and the ultrasound contrast was saved as a dynamic image.

The contrast agent was SonoVue produced in Italy, the main components of which were sulfur hexafluoride gas, the white freeze-dried powder of dipalmitoyl phosphatidylglycerol, l-alpha-phosphatidylcholine, distearoyl, and ethylene glycol. After the contrast agent was injected into the blood circulatory system, it was expelled from the body through breathing. Then, 5 mL of normal saline was mixed well with 59 mg of sonovir contrast agent powder to obtain a suspension. Subsequently, about 2 mL of contrast agent was injected through the median elbow vein. The three-dimensional ultrasound contrast mode was adopted to check and record the whole process. Then, the perfusion method of the contrast agent in uterine lesions and normal uterine muscles layer and the change characteristics of the echo intensity were observed. The main detection parameters of CEUS include AT, RT, TTP, and IMAX.

Detection standard of CEUS image: the perfusion phase of the uterus area is divided into early and late phases. Early enhancement refers to the time echo enhancement reaches the peak from uterine artery to muscular layer perfusion; late enhancement refers to the period in which the echo intensity of the myometrium decreases from its peak to the intensity before the radiographic examination. The echo intensity of the muscle layer is enhanced horizontally and divided into three levels: high, equal, and low. High enhancement means that the gray scale of the target area is brighter and the intensity is higher than that of the surrounding muscularis tissue area. The equal enhancement refers to that the intensity of the target area is not significantly different from that of the surrounding muscularis tissue area. Low enhancement refers to a lower intensity of the target area than the surrounding muscularis.

Enhanced Mode. Diffuse type: multiple parts are strengthened at the same time, without obvious directionality; centripetal type: the periphery is first strengthened and then the center is strengthened; eccentric type: the center is first strengthened, and then the strengthening spreads to the periphery; ring-enhanced type: the nodule is strengthened at the periphery and there is no enhancement inside.

Image fusion: the spatial multipoint alignment method is adopted in the internal calibration method to perform image alignment. Then, 3 or more clear and distinguishable anatomical calibration points are selected on the CT/MRI image. Then, the scaling point of the corresponding position on the ultrasound image is found and determined. The fusion is acceptable after the positioning of each point is completed. The standard for successful fusion: the distance between the same anatomical structure is measured after the two images are superimposed, and the position difference within 5 mm is considered as the successful fusion. Then, the time required for image alignment is recorded.

2.3. Statistical Methods. The data were processed by SPSS22.0, the mean ± standard deviation was how the measurement data were expressed, and the t-test and one-way analysis of variance were performed on the measurement data. The count data were expressed as a percentage, and the chi-square test was adopted. The prices of graded data were compared by the rank-sum test, and $P < 0.05$ indicated that the difference was statistically significant.

3. Results

3.1. Ultrasound Images. Figure 1 shows the CEUS image of a patient with adenomyosis. Figure 1(a) was the original image, and Figure 1(b) was the ultrasound image after three-dimensional fusion. The left image was for a patient with diffuse adenomyosis, and the right image was for a patient with localized adenomyosis. It was evident that the patient had severe adenomyosis, the lesion was clearly visible, and further treatment was needed.

3.2. CEUS Detection Results. It was evident from Tables 1 and 2 that the enhancement methods in Groups A and B were mainly dendritic enhancement. Besides, there was gradual enhancement from the peripheral irregular nodules to the center. Most of the patients had uneven enhancement, and the level was higher than the surrounding muscle tissue. After the enhancement peaks, there was no obvious boundary in the lesion area. When it subsided, it was synchronized with the surrounding muscles. In Group C, dendritic enhancement was observed, and the whole muscle layer showed uniform enhancement after the enhancement reached the peak. No filling defect area was found, and the regression was carried out from the center to the periphery.

In 40 cases of localized adenomyosis, the CEUS revealed that 32 cases (80.0%) had dendritic enhancement in the early stage of contrast, and 5 cases (20.0%) had gradual enhancement from peripheral irregular nodules to the center. After enhancement peaks, there was no obvious boundary between the lesion area and the surrounding area. 11 cases (27.5%) had uniformity enhancement, 29 cases (72.5%) had unevenness enhancement, 23 cases (57.7%) had high enhancement, 8 cases (20%) had equal enhancement, and 9 cases (22.5%) had low enhancement. When the contrast agent subsided, the lesion area and the surrounding muscle layer disappeared synchronously.

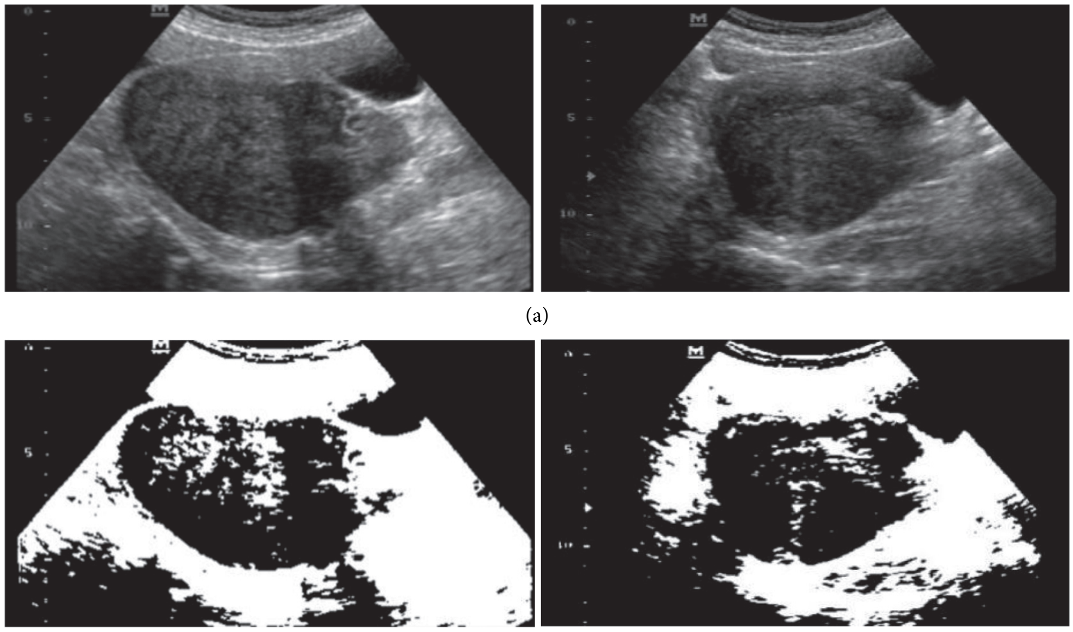
In 48 cases of diffuse adenomyosis, the contrast-enhanced ultrasonography revealed that 42 cases (87.5%) had dendritic enhancement in the early stage of contrast, and 6 cases (12.5%) had gradual enhancement from peripheral irregular nodules to the center. After enhancement peaks, there was no obvious boundary between the lesion area and the surrounding area. 18 cases (37.5%) had uniformity enhancement, 30 cases (62.5%) had unevenness enhancement, 30 cases (62.5%) had high enhancement, 7 cases (14.5%) had equal enhancement, and 11 cases (22.9%) had low enhancement. When the contrast agent subsided, the lesion area and the surrounding muscle layer disappeared synchronously.

The CEUS results of 45 cases of the normal uterus were as follows: in the early stage, the periphery of the myometrium showed dendritic enhancement to the endometrium surface. If the entire myometrium showed enhancement such as uniformity, then the peak was reached and there was no filling defect. When the contrast agent faded, the entire muscle layer began to fade from the center to the periphery.

3.3. Comparison of Parameter Levels of TIC. The AT refers to the time from the start of the contrast agent injection to the start of the perfusion in the observation area; the TTP refers to the time from the beginning of the contrast agent to the maximum average intensity of the observation area; the IMAX refers to the average maximum intensity of the observation area; and RT refers to the time it takes for IMAX to rise from 10% to 90%. It was evident from Table 3 and Figures 2–5 that there was no obvious difference in AT between all subjects ($P > 0.05$). In contrast with Group C, both Groups A and B had shorter ART, faster TTP, and higher IMAX ($P < 0.05$), but there was no obvious difference between the two in the above three indicators.

4. Discussion

Adenomyosis refers to the endometrial glands and stroma ectopia in the myometrium, accompanied by compensatory hyperplasia of uterine smooth muscle and fibrous tissue. The



(a)

(b)

Figure 1: Contrast ultrasound images.

Table 1: Comparison of CEUS.

Group	Enhanced shape		Enhancement method	
	Dendritic	Centripetal	Even	Uneven
Group A ($n = 40$)	32 (80.0%)	5 (20.0%)	11 (27.5%)	29 (72.5%)
Group B ($n = 48$)	42 (87.5%)	6 (12.5%)	18 (37.5%)	30 (62.5%)
Group C ($n = 45$)	45 (100%)	0 (0%)	45 (100%)	0 (0%)
χ^2	3.32		67.8	
P	0.12		≤0.001	

Table 2: Comparison of contrast enhancement levels.

Group	High enhancement	Equal enhancement	Low enhancement
Group A ($n = 40$)	23 (57.7%)	8 (20%)	9 (22.5%)
Group B ($n = 48$)	30 (62.5%)	7 (14.5%)	11 (22.9%)
Group C ($n = 45$)	0 (0%)	45 (100%)	0 (0%)
χ^2		18.43	
P		≤0.001	

Table 3: Comparison of parameter levels of TIC.

Group	AT (s)	RT (s)	TTP (s)	IMAX (dB)
Group A ($n = 40$)	13.23 ± 2.34	17.32 ± 4.98	28.56 ± 3.21	54.62 ± 3.32
Group B ($n = 48$)	12.34 ± 3.12	16.32 ± 4.23	27.33 ± 4.12	55.23 ± 4.21
Group C ($n = 45$)	12.50 ± 2.54	23.09 ± 5.21	32.90 ± 2.87	49.13 ± 3.77
F	4.32	24.98	36.43	30.21
P	0.09	≤0.001	≤0.001	≤0.001

ectopic endometrium can undergo changes similar to the eutopic endometrium with the ovarian cycle, but it is not synchronized with the eutopic endometrium. The growth of basal cells of the endometrium is the general pathogenesis of the disease toward the myometrium. Studies have shown that the interface between the endometrium and the muscle layer influences the pathogenesis of adenomyosis. Under normal circumstances, the endometrium of the cavity organs

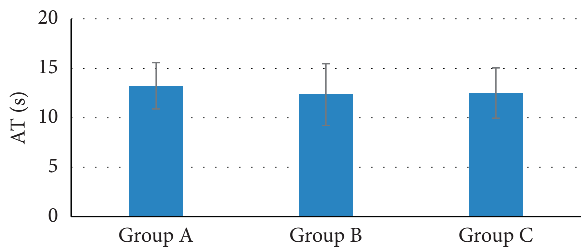


Figure 2: Comparison of the AT.

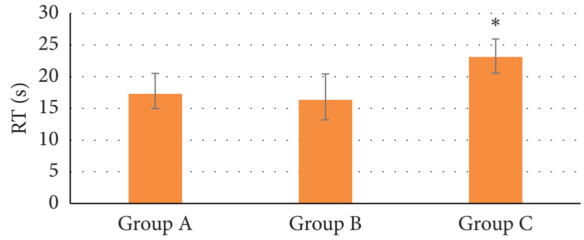


Figure 3: Comparison of the RT. Note: * indicates that the difference was observable compared with patients with adenomyosis ($P < 0.05$).

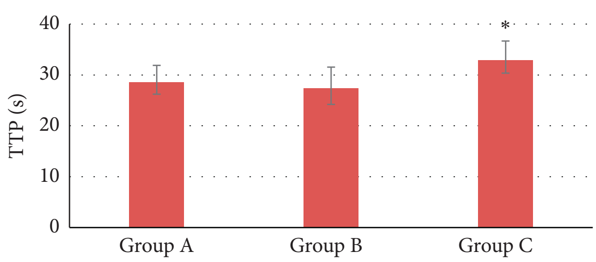


Figure 4: Comparison of TTP. Note: * indicates that the difference was observable compared with patients with adenomyosis ($P < 0.05$).

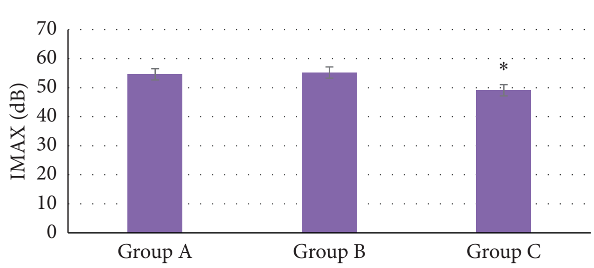


Figure 5: Comparison of IMAX. Note: * indicates that the difference was observable compared with patients with adenomyosis ($P < 0.05$).

in the body grows into the cavity. The reason is that the submucosa has a certain inhibitory effect on the reverse growth of the endometrium. However, there is a lack of submucosa between the endometrium and the muscularis. Under normal circumstances, the endometrial base has a certain resistance to the endometrium, but in some special cases such as uterine cavity infection, trauma will destroy the inhibitory effect of the basal layer of the endometrium, resulting in the in-layer growth of endometrial muscles. Existing studies have shown that the interface between the myometrium and the endometrium plays an important role in the occurrence and development of adenomyosis. Ultrasound testing is a common way to evaluate patients with the endometrial disease. Observing the characteristics of the patient's lesion boundary, morphology, internal structure, hemodynamics, and blood flow distribution is of great significance to clarify the nature of the lesion and the scope of invasion, thus improving the diagnosis rate [14, 15]. This is consistent with the results of this study.

The imaging sequence of contrast-enhanced normal uterine ultrasound is arcuate arteries, radial arteries, and spiral arteries, and its trend is consistent with the uterine vascular structure [16]. In this study, as for the early manifestations of CEUS enhancement in the uterus of the 45 normal patients, they were all enhancement from the peripheral branches of the myometrium to the endometrial surface. From the outside to the inside, the enhanced signal gradually branched from the thick strip to the thin strip, and finally, the whole myometrium showed even enhancement. The main reason was that the spiral artery was a branch of the ascending uterine artery, and its diameter was small. Besides, the contrast agent fills slowly. Therefore, the spiral artery was finally developed and the main uterine artery was distributed on both sides of the uterus. Therefore, the contrast agent increased from the edge to the center. Then, there was centripetal enhancement toward the center. The initial enhancement methods for both the diffuse and localized types were mainly dendritic enhancement. After enhancement peak, all lesions had no boundaries. The peak intensity was mainly uneven and high enhancement, and the disappearing was synchronized with the surrounding muscle layer. Although adenomyosis shows mass echoes similar to uterine fibroids on ultrasound images, it is not a real tumor. It is formed by the localized distribution of endometrial glands and stroma when they invade the myometrium. Similar to diffuse lesions, there is no obvious boundary, and no pseudo-capsule like uterine fibroids is formed. Therefore, there is no ring-shaped or semi-ring-shaped enhancement and peaked lesions in ultrasound images [17].

There was no significant difference between all subjects in enhancement methods, the border after reaching the peak, and the way of regression. The main reason may be that under the pathological characteristics, the arterial trend of adenomyosis lesions was consistent with that of positive uterine arteries, and no visible proliferative vascular network was formed. In addition, the blood vessels in the lesion were diffused, with no obvious boundary with the surrounding area and no envelopment was formed [18]. There were differences in peak intensity uniformity of the three groups. The peak intensity in Groups A and B was mainly uneven, while Group C showed even enhancement. In terms of peak intensity, there were obvious differences between the three groups. Groups A and B showed mainly high enhancement, while Group C showed equal enhancement, which may be related to more blood vessels in the adenomyosis lesion than the normal muscle layer. Because there was much vascular proliferation and expansion in the focal area of adenomyosis patients, the intensity of the contrast agent was higher than the normal muscle layer at the peak. Some patients showed low enhancement. The main reason was that there were more bleeding sacs in the lesion area and fewer contrast agents reached the lesion. Therefore, the overall lesion showed low enhancement.

5. Conclusion

In the study, the effect of CEUS in the diagnosis of adenomyosis was explored. It was found that the enhancement method, enhancement uniformity, and enhancement level of the ultrasound scan in patients with adenomyosis were obviously different from those of normal uterus. In contrast with Group C, the RT of ultrasound scan in Groups A and B was lower, the TTP was faster, and IMAX was higher. Further analysis revealed that there was concentricity, uneven high enhancement in CEUS in Groups A and B. Besides, in contrast with Group C, the RT was shorter, TTP was faster, and IMAX was higher. However, the sample size of the study is small and it cannot provide reliable research data for clinical research. In follow-up studies, the diagnosis of CEUS in gynecological diseases should be discussed, and more testing methods should be incorporated to improve the diagnosis rate of patients. This study highlighted the effectiveness and safety of 3D CEUS in the diagnosis of adenomyosis and provided enlightening clinical data for the diagnosis of adenomyosis.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

Yiqun Zhang and Lu Xue contributed equally to this work.

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